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Nip roll of a paper or board machine

The invention relates to a roll according to the preamble of claim 1.

Various calendering concepts are known from prior art, one of which is long nip calendering. Long nip calendering can be based on shoe press technology or on belt/roll technology. In shoe calendering, shoe press technology known from the press section is used and the shoe roll comprises a shoe, loading elements, a lubricating oil system and a belt. A thermo roll is used as the other roll of the calendering nip, which roll can be a water-, steam-, oil-, or induction-heated roll. A belt calender comprises a thermo roll, a belt loop and a backing roll, which may be either a hard or a soft roll, and the belt circulates over the backing roll and the guide/tension rolls. In the long nip calendering process large amounts of heat are transferred from the thermo roll to paper and the great heat amounts generate high thermal stresses and rapid stress gradients in the thermo roll, in which case the properties (durability) of the cast iron rolls used at present are no longer sufficient for the desired process conditions. In addition, the stress states in the roll during its use may vary in the direction of thickness of the material of the roll, to which the materials used today, e.g. chill casting, are poorly resistant.

In today's paper and board machines the calendering process is often connected as an on-line unit to a paper or board machine, in which case, e.g. the changing and cleaning of the roll have to take place quickly in order to avoid wasting valuable capacity. This is problematic, since, according to industrial safety regulations, the temperature of a hot roll must be under 60°C before it can be changed and, on the other hand, the working temperature of the roll is as high as 200°C. Prior art chilled rolls withstand a temperature change rate of 2°C/min., due to which a considerable amount of time and capacity has been lost in connection with the

changing or cleaning of the roll. This has even partly led to the attempt to clean the rolls quickly, for example with a pressure washer, with the result that the roll cools down too quickly with respect to its strength, and thus serious damage may have been caused to the roll.

Rolls having a steel surface are also known from prior art - one example being disclosed in US patent 6,203,307. In the hot soft nip calender disclosed in the patent, rolls with a steel outer surface are used as calender rolls to be heated. In traditional soft calendering the heat amounts transferred are, however, considerably smaller than in long nip calendering.

Arrangements in which the wear resistance of the steel roll has been provided by coating are known from prior art. Some such arrangements are disclosed in US patents 4,452,647 and 5,167,068.

A very long nip, typically being over 30 mm, and high temperatures, the surface temperature of the roll typically being over 160°C (the interior of the roll can be even considerably hotter), and possibly moisturizing of the paper/board web with water or steam are needed in the long nip calendering process. These factors do not enable the manufacture of the machine, especially of the thermo roll of the nip, by means of the traditional technique, or, if manufactured traditionally, the machine has a low fault tolerance in case of a process failure.

In modern paper and board machines rolls, particularly nip rolls, which withstand dramatic changes in the process conditions are needed, and it is an important object of the invention to provide such a roll.

A special object of the invention is to provide a long nip calender roll that withstands the high thermal stresses caused by the long nip process and enables an efficient heat transfer to paper.

It is an object of the invention to provide a roll resistant to thermal shock. Thermal shock has been dealt with, e.g. in the book "The Science and Engineering of Materials" by Donald R. Askeland, pp. 740-741, Chapman & Hall, 1996 (Third S.I. Edition).

An object of the invention is also to provide a roll that withstands rapid temperature changes.

To achieve the afore-mentioned objects and those that come out later the long nip calender roll according to the invention is mainly characterized in what is presented in the characterizing part of claim 1.

The problem underlying the invention can be solved in a new and inventive way by changing the material used from cast iron to steel, meaning that, according to the invention, the heatable thermo roll of a long nip calender is manufactured of steel.

The roll according to the invention withstands thermal shock and its thermal shock coefficient is over 6000 W/m^2, which is due to the properties of the roll: ductility, very high strength properties, wear resistance. A roll having, at the same time, these three important qualities, with which considerable advantages are achieved, is not known from prior art. The material of the roll according to the invention is pure and homogeneous in the thickness direction of the wall; most appropriately the entire layer involved in the heat transfer process is homogeneous i.e. comprises one phase i.e. one crystal structure. Most advantageously the roll wall is martensite or bainite and does not contain retained austenite. The roll may also be entirely homogeneous.

The dynamic properties of the roll according to the invention are at a high level, whereby the vibration problems are diminished.

The properties of the roll according to the invention, most appropriately a steel roll in a quenched and tempered state, are preferably the following: surface hardness is 400-500 HV_{20}, modulus of elasticity over 200 000 MPa, tensile strength over 1 000 MPa, bending fatigue strength over 350 MPa, thermal conductivity over 30 W/mK, elongation at fracture over 7 %, and dynamic ductility over 20 J.

The roll according to the invention is also particularly well suitable for use in future processes, since it is very durable thanks to good ductility, strength and wear resistance properties and, in addition, its structure is very homogeneous, which also adds to its durability.

The material of the roll according to the invention is most preferably tempering steel and its crystal structure is most appropriately martensitic or bainitic. Most advantageously the material of the roll according to the invention is homogeneous tempering steel which has been induction hardened and tempered.

In this description a nip roll refers to a roll forming a nip with another roll, in which the contact between the rolls is usually given in MPa units and the nip length is over 4 mm.

According to an advantageous characteristic of the invention the surface properties, e.g. hardness, of the roll can be altered, if necessary, by hard coating the roll, whereby the hardness of the base material of the roll may be of the order of 250 MPa.

The roll according to the invention advantageously has one or more of the following properties:

- The shell of the roll is forged from a steel slab or it is a steel casting or otherwise manufactured of steel, such as, by bending from a plate.

- The roll is heated, for example by means of a heat transfer medium flowing inside the roll, e.g. by means of water, steam, oil, air; by resistors, external or internal induction; there can be a heat production unit inside the roll, or by means of a combination of two or more of the above. The roll is most appropriately heated so that the heat is distributed evenly over the surface of the shell of the roll.
- The steel shell of the roll may be coated (e.g. welding or plasma spraying) with a wear resistant material, with which the surface hardness is increased. The coating may also serve as a protection against chemical wear.
- The steel shell of the roll is surface hardened or through hardened or unhardened. Suitable hardening methods include, for example, induction hardening, flame hardening, laser hardening, case hardening, nitrate hardening or other such heat treatment according to the quenching and tempering treatment.
- The steel roll can also be manufactured of one or more different materials.
- The roll surface made of a different material may also be a several millimetres thick shell enveloping the inner part of the roll, e.g. a tempering steel shell over a cast iron central portion.
- The structure of the roll may enable the evaporation of water in the nip. The roll may be a conventional roll or the roll may be formed only of a rotating shell, such as a roll similar to the one marketed by the applicant under the trademark SymRoll.
- The roll can be cooled and heated by means of a medium, e.g. water. The properties of the roll surface, e.g. hardness and thermal conductivity, may vary in the cross machine direction (direction of the roll axis).

Thermal shock i.e. heat shock in materials is affected by several factors: the coefficient of thermal expansion, thermal conductivity, the modulus of elasticity, fracture stress and phase transformations. Thermal shock can thus be derived from the equation $\frac{\sigma_f k}{E\alpha}$, where

σ_f = the fracture stress of the material, k = the thermal conductivity, E = the modulus of elasticity and α = the linear coefficient of thermal expansion.

The roll according to the invention is advantageously suitable for use as a nip roll of a paper or board machine, especially in nips in which a great heat transfer from the roll to the web occurs. Advantageous applications are, for example, thermo roll of a calender (e.g. super-, multiroll, OptiLoad, long nip and soft calenders).

The roll according to the invention withstands rapid temperature changes, whereby, for example, it does not take as much time to change or clean it and, in addition, the heating and cooling phases, in which a lot of capacity is lost, naturally become considerably quicker.

The following table shows in an exemplifying manner a comparison between the material properties of a prior art roll manufactured of chill casting material and of a roll manufactured of tempering steel according to a preferable application of the invention.

Property	**Chill casting**	**Tempering steel**
Tensile strength at fracture	about 250 N/mm^2	about 1400 N/mm^2
Yield stress	no yield stress (white cast iron)	about 1100 N/mm^2
Elongation A5	no remarkable elongation less than 0.2 %	more than 8 %
Surface hardness	about 550-590 HV20	420-480 HV20 (through the entire shell of the roll)
Thermal conductivity	24 W/mK (white cast iron) surface layer about 10 mm	30-40 W/mK
Thermal conductivity	48 W/mK (grey cast iron) interior	